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INVESTIGATION INTO THE RELATIONSHIP BETWEEN LODGING, STEM ANATOMY, DEGREE OF STEM LIGNIFICATION AND SUSCEPTIBILITY TO MYCOSPHAERELLA PINODES I

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Investigation into the relationship between lodging, stem anatomy, degree of stem lignification and susceptibility to *Mycosphaerella pinodes* in field pea

Final Report

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S. Banniza, T. Warkentin, A. Vandenberg, A. Davis

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(a) Abstract/Summary

The relationship between lodging, stem anatomy, degree of stem lignification and susceptibility to *Mycosphaerella pinodes* was investigated in field experiments at Saskatoon and Outlook in 2000, 2001 and 2002. In 2000, partial flooding at Outlook resulted in poor plant establishment, while severe drought at Saskatoon in 2001 and 2002 lead to poor germination, small plants and lack of disease development. Therefore, only results from experiments at Saskatoon (2000) and Outlook (2001 and 2002) are presented.

Significant differences were observed in susceptibility to the pathogen and to lodging among the varieties in the test. Trends were similar as in all years and AC Tamor was among the varieties with highest disease rating and highest lodging score. Correlation analysis of disease data with yield and gross-morphological characters showed that higher disease was correlated to higher lodging of pea plants. Among anatomical characters of stem sections, the proportion of supportive tissue and pith tissue were correlated with lodging and disease development. A higher ratio of supportive tissue resulted in lower lodging and disease severity scores, while more pith tissue in stems was correlated with more disease and lodging. Analysis of lignin, fiber and cellulose revealed that the percentage of lignin and fiber content in pea stems was negatively correlated with lodging and disease severity on whole plants. Cellulose was also negatively correlated with disease severity on whole plants.

(b) Executive Summary

Lodging and susceptibility to *Mycosphaerella pinodes* are two major constraints to pea production. No major genes are available for resistance to *M. pinodes* or for resistance to lodging. Field experiments were conducted at Saskatoon and Outlook to evaluate the relationship between lodging, susceptibility to *M. pinodes*, and lignification of pea stems. Twenty field pea varieties were evaluated for susceptibility to mycosphaerella blight, lodging and various anatomical characteristics at two locations over the period of three years. Due flooding in 2000 at Outlook and drought conditions at Saskatoon in 2001 and 2002, only results from Saskatoon in 2000 and from Outlook in 2001 and 2002 are

presented. Throughout the field season, measurements of plant height, number of internodes, internode length and diameter, disease severity and lodging were recorded, and stem samples were collected for subsequent stem section analyses.

Overall, CDC Peko, Keoma and AC Tamor had lowest lodging resistance while Espace, Carneval, Integra, Nitouche, CDC 0001 and Eclipse remained relatively upright until harvest. Significant differences were also observed in plant height, the number of nodes as well as internode length and diameter at various heights. Plant height as well as the number of internodes had little value in predicting lodging resistance in the pea varieties.

AC Tamor was among the varieties with the highest disease rating, along with CDC Peko and Grande. Varieties with lowest disease ratings were CDC 0001, Espace, Eclipse, Miami, CDC 0109, Carneval, Integra and Radley. In many varieties, higher disease severity coincided with higher lodging scores and lodging data correlated well with disease ratings.

AC Tamor also had significantly lower amounts of lignin and fiber in its stems, and this was negatively correlated with lodging and disease severity.

(c) Technical Report

Background:

Resistance to lodging and infection with *Mycosphaerella pinodes* are two major objectives in pea breeding programs in Saskatchewan. It is estimated that lodging of pea causes yield reductions of approximately 10% on average due to losses during harvesting and poorer quality of seed. Preliminary studies at the University of Saskatchewan suggested that a correlation exists between stem anatomy (in particular xylem fibers) and the tendency for pea varieties to lodge. The relatively lodging-resistant variety Carneval showed a higher area of xylem in stem sections with higher amounts of xylem fibers in comparison to two lodging-susceptible varieties. Lodging has also been associated with an increase in infection with *Mycosphaerella pinodes*, a major pathogen in pea. Higher disease severity can partly be attributed to a more favorable microclimate for the fungus

in lodged peas, but may also be ascribed to differences in stem anatomy. It is well documented that plants produce a number of chemicals that inhibit or reduce infection by certain pathogens. Among those, phenolic substances such as lignins play a major role in the plant's defense strategy.

Project Objectives:

The objectives of this research project are:

1. To clarify the correlation between lodging and susceptibility to *Mycosphaerella* blight.
2. To investigate the effect of stem anatomy on lodging and susceptibility to *Mycosphaerella* blight.
3. To identify markers which can be used to select suitable breeding material through more efficient tests than field screening.
4. To streamline screening for lodging resistance and resistance to *Mycosphaerella* blight.

Materials and Methods:

Field experiments

Two experiments were conducted in 2000, 2001 and 2002, one at Saskatoon (rain fed) and one at Outlook under irrigation. In 2000, the following ten varieties were grown: Integra, Keoma, AC Melfort, Carneval, CDC Peko, AC Tamor, Carrera, Espace, Nitouche, and Radley. AC Tamor had very low germination rate and plots of this variety were therefore not evaluated that year. In 2001 and 2002, an additional 10 varieties were tested, bringing the total to 20 varieties: Integra, Keoma, AC Melfort, Carneval, CDC Peko, AC Tamor, Carrera, Espace, Nitouche, Radley, Courier, 203 PMR-16, Grande, Alfetta, CDC Mozart, Eclipse, Miami, CDC 0001, CDC 0109, and Eiffel. Varieties were seeded in 8-row plots, with row length of 3.7 m, and row spacing of 0.30 m in three replicates (RCBD). Plots were inoculated with pea straw infested with *Mycosphaerella pinodes* at a concentration of about 75 cm^3 per plot. During the growing season, the following observations were recorded at approximately 10 day interval: plant height (in cm), number of nodes, length (in cm) and diameter (in mm) of the internodes between

nodes two and three, five and six, and eight and nine, severity of *Mycosphaerella* infection on whole plants (on a 0 to 9 scale, Xue et al. 1996) and on pods (on a 0 to 5 scale, Tivoli 1977) in all years, on stems (on a 0 to 11 scale, Horsefall & Barratt 1945) in 2001 and 2002, and plant lodging (on a 1 = erect to 9 = flat). For this purpose 5 plants were randomly selected, marked and repeatedly measured. Final disease and stem ratings were analyzed and are discussed. Due to partial flooding of the experiment at Outlook, only data from Saskatoon is presented for 2000. Severe drought in 2001 and 2002 resulted in poor plant development at Saskatoon and no mycosphaerella blight developed. Therefore, only data from Outlook are presented for 2001 and 2002. Dates of seeding, dates of final rating and stem sampling, and of harvest are presented in Table 1. Days to flowering, days to maturity, yield and the number of side branches in varieties in 2001 and 2002 are summarized in Table 6, but are not discussed in detail.

Table 1: Dates of seeding, inoculation, stem sampling, rating of mycosphaerella blight and lodging, and harvest of field pea in experiments at Saskatoon and Outlook to study the relationship between lodging, stem anatomy, stem lignification and resistance to *Mycosphaerella pinodes*.

Dates of	Saskatoon (2000)	Outlook (2001)	Outlook (2002)
Seeding	May 5	May 3	May 9
Inoculation	June 23	June 29	July 3
Stem sampling	August 5	August 1	August 3
Mycosphaerella blight rating	August 5	August 8	August 16
Stem measurements	August 17	August 9	August 19
Lodging	August 5	August 8	August 16
Harvest	August 18	August 20	September 10

Analysis of stem section

Pieces of pea stems were preserved for laboratory analysis of stem sections of all varieties. Three stem sections of each variety of internode 2-3 and internode 8-9 from Saskatoon (2000), and from Outlook (2001 and 2002) were photographed under the microscope and the area of various tissue types was determined digitally using ImageJ (Wayne Rasband, Research Services Branch, National Institute of Mental Health, Bethesda, Maryland, USA). The number of sclerenchyma caps, and the proportion of the

following tissue types of the total stem section were analyzed: supportive tissue, pith cavity, pith tissue, the area of sclerenchyma caps and xylem.

Analysis of fiber, lignin and cellulose in pea stems:

Acid detergent fiber (ADF): A sample of 0.5 g of air-dried, ground pea stem was passed through a 1 mm screen put into filter bag after sealing the bag with bag sealer. Twenty-four bags were placed into a bag suspender, in the ANKOM FIBER ANALYZER vessel and 100 ml acid detergent solution was added to each bag. Bags were heated and agitated for 60 minutes. Samples were rinsed three times with hot water (90-100 ^{O}C) for 5 min or until the water had a neutral pH. Excess water was removed and the bags were soaked in acetone for 3 minutes. After evaporation of the acetone, bags were completely dried at 150 ^{O}C for at least 2 hours. After drying, bags were directly placed into moisture stop and weighed. The amount of ADF (was calculated as follows: ADF = $(W_3 - (W_1 * C_1))$ $*100/W_2$, with W_1= weight of bag, W_2=sample weight, W_3= weight of bag incl. sample after extraction process, and C_1= weight of oven dried bag/original bag weight.

Acid Detergent Lignin (ADL): Dried plants samples in bags from the ADF analysis were submerged into approximately 250 ml of 72 % H_2SO_4, agitated twice every 30 minutes for 3 hours after which the H_2SO_4 was poured off. Samples were rinsed in water at 90-100 ^{O}C until the pH of the water reached neutral. Samples were dried at 150 ^{O}C for 4 hours, placed directly into moisture stop and weighed. The percent of ADL was calculated as follows: ADL = $(W_3 - (W_1 * C_1)) *100/W_2$, with W_1= weight of bag, W_2=sample weight, W_3= weight of the bags incl. sample after extraction, C_1=weighed of oven dried bag weight /original bag weight.

Cellulose: The percentage of cellulose in the sample is the difference between the percentage of fiber and the percentage of lignin.

Statistical analysis

All statistical analyses were conducted in SAS (SAS Institute Inc., Cary, NC, USA). Data were tested for normality and transformed where necessary. Wherever possible, data from different years were pooled. Disease data, lodging data and the length of internode 2-3 (2001 and 2002) were analyzed by ranks using the Kruskall-Wallis test followed by a non-parametric multiple

comparisons of means. The number of sclerenchyma caps of both internodes was analyzed using the GENMOD procedure assuming a Poisson distribution and specifying a log link function. All other data were analyzed using the GLM procedures. Means were separated by Tukey test. A Pearson correlation analysis was conducted with field data and stem anatomy data from Outlook 2001 and 2002.

Results and Discussion:

Field experiments

Plant development at Saskatoon (2000) and at Outlook (2001 and 2002) was good and plant height ranged from 50 to 92 cm (Table 2). Plant height of varieties was relatively consistent over the years. Among the tall varieties were Courier, Grande, CDC Peko and Nitouche, while Alfetta, AC Melfort and Carrera were distinctly shorter varieties. On average, varieties with taller plant growth also had a higher number of nodes ($R = 0.61$, $P < 0.0001$). For example, Courier, Grande, CDC Peko and Nitouche had on average between 24 and 26 nodes in 2001 and 2002 at Outlook in contrast to 19 to 23 nodes found in Alfetta, AC Melfort and Carrera (Table 2). Plant height and the number of nodes were correlated to lodging ($P = 0.015$ and $P = 0.026$, respectively), but both characteristics only explained 22% (plant height) and 20% (number of nodes) of the variation found among varieties with respect to lodging.

Plant reaction to lodging was consistent over the years. AC Tamor, Keoma, CDC Peko and Radley lodged severely every year, while Carneval, CDC 0001, and Integra were consistently more resistant to lodging (Table 2). Some varieties, however, varied from year to year. For example, Eclipse was rather susceptible to lodging in 2001 at Outlook, but was significantly more upright in 2002.

Lodging was not consistently correlated to the stem diameter at various heights or the length of the internodes. The correlations between lodging and internode diameter, and lodging and internode length between nodes 5 and 6 were significant ($P = 0.016$ and $P = 0.007$, respectively), but again explained relatively little of the variation (less than 25%).

Internode length between nodes 2 and 3 varied little between varieties and differences were not significant (Table 3). At internode 5-6, length ranged from 1.5 to 2.7 cm, and internodes between nodes 8 and 9 increased to 2.6 to 3.8 cm. Internode length at various heights were highly significantly correlated. Varieties with long internodes were Eiffel and Integra; those with short internodes were 203-PMR-16 and AC Melfort. Interestingly, internode length at internodes 2-3 and 5-6 were not correlated to height, but internode length 8-9 was correlated to height ($R = 0.23$, $P = 0.01$).

Highly significant correlations were also found between internode diameters at various heights, which ranged from 2.2 to 3.0 mm at internode 2-3, 2.6 to 3.6 mm at internode 5-6, and 3.2 to 4.4 mm at internode 8-9 (Table 4). Miami, Alfetta and Carneval had the thinnest stems, while CDC Peko and Courier were among those with the thickest stems. In contrast to internode length, internode diameter was correlated to plant height ($R = 0.36$, $P < 0.0001$ at internode 2-3; $R = 0.46$, $P < 0.0001$ at internode 5-6, $R = 0.49$, $P < 0.0001$ at internode 8-9).

Mycosphaerella blight development was good at Saskatoon in 2000, and at Outlook in 2001 and 2002. Severity ranged from 6.5 to 8.8 on whole plants, 1 to 4 on pods, and from 30% to 91% on pea stems (Table 5). Severity ratings on whole plants, pods and stems were correlated ($R = 0.57$, $P < 0.0001$ for whole plant disease severity and pod severity; $R = 0.44$, $P < 0.0001$ for whole plant disease severity and stem severity, $R = 0.73$, $P < 0.0001$ for pod and stem severity). Varieties with relatively good overall resistance were CDC 0109, Integra and Radley while high severity levels were recorded on AC Tamor, CDC Peko and Grande. Disease severity was correlated with lodging ($R = 0.54$, $P < 0.0001$ for whole plant ratings; $R = 0.57$, $P < 0.0001$ for pod ratings; $R = 0.45$, $P < 0.0001$ for stem ratings).

Results from field ratings suggest that gross-morphological features such as plant height, internode length and diameter have limited value in predicting lodging resistance. The

study confirmed, however, that varieties with less resistance to mycosphaerella blight also tend to show more lodging.

Analysis of stem sections

Analysis of the number of sclerenchyma caps (SC), which represent stem reinforcement structures, revealed that there was no significant difference between varieties (Table 7). More SCs were counted in the upper internode compared to the internode 8-9. However, when considering the ratio of SC area to the total stem section area, there was very little difference between internodes 2-3 and 8-9. This is due to the fact that pea stems become thicker the further they grow. Some differences were observed when analyzing the proportion of the stem sections that represented SCs, in particular at internode 2-3. In 2000, Keoma had the highest ratio of SCs to stem diameter, while Radley had the lowest. In 2001 and 2002, Eiffel had a significantly higher SCs ratio compared to most other varieties. At internode 8-9, differences were only found in 2002, where Eiffel, Nitouche and Integra had a higher SC ration compared to 203-PMR-16.

Low levels of variation were also observed in the proportion of supportive tissue (ST) at internode 2-3, and slightly more at internode 8-9 (Table 8). The ST ratio at internode 2-3 was negatively correlated with lodging and disease rating on plants, and in particular with lodging (R = -0.28, $P < 0.0001$ for whole plant ratings; R = -0.38, $P < 0.0001$ for pod ratings; R = -0.27, $P = 0.003$ for stem ratings; R = -0.46, $P < 0.0001$). This relationship was similar for the ST at internode 8-9.

Pith cavity was only analyzed for data from internode 8-9 because it was infrequently developed at internode 2-3 and only very small. Variation was observed at internode 8-9 where Keoma had the smallest cavity, while Mozart, CDC 0109, Espace, AC Tamor and CDC Peko were among those with the biggest pith cavity in relation to the stem diameter (Table 9). While pith cavity was not correlated with lodging or disease severity, the ratio of pith tissue at internode 8-9 where most of the variation was observed (Table 10), was positively correlated with lodging and mycosphaerella blight on stems and pods(R = 0.41,

$P < 0.0001$ for lodging; $R = 0.36$, $P < 0.0001$ for pod ratings; $R = 0.27$, $P < 0.001$ for stem ratings).

Very little variation in the proportion of xylem was observed among varieties (Table 11) most of which was found at internode 8-9. However, the amount of xylem did not appear to influence lodging or disease development.

Analysis of fibre, lignin and cellulose in pea stems

Analysis of fibre, lignin and cellulose in samples from the Saskatoon 2000 experiment revealed significant differences between varieties in the proportion of these compounds in pea stems. AC Tamor had a significantly lower proportion of fibre (50%) in its stems compared to all other varieties (Table 12). Most other varieties had greater than 60% fibre in stems. Fibre content was negatively correlated with lodging ($R = -0.62$, $P = 0.0005$) and with disease severity on the whole plant ($R = -0.63$, $P = 0.0004$), but not with disease rating on pods. Lignin content was also lowest in AC Tamor with 13 % compared to 19% in Carneval, which had the highest proportion of lignin in stems. Similar to fibre, proportion of lignin was also negatively correlated with lodging ($R = -0.68$, $P < 0.0001$) and with disease severity on the whole plant ($R = -0.43$, $P = 0.0238$). AC Tamor also had a significantly lower proportion of cellulose in its stems (38%) compared to all other varieties that had more than 40 % cellulose. Cellulose was negatively correlated with disease severity on the whole plant ($R = -0.53$, $P = 0.0045$), but not with lodging.

Table 2: Plant height, lodging severity and the number of nodes of field pea varieties in field experiments at Saskatoon (2000) and Outlook (2001/02) to study the relationship between lodging, stem anatomy, stem lignification and resistance to *Mycosphaerella pinodes*.

	Plant height (cm)			Lodging				Number of nodes	
Variety	2000	2001	2002	2000	2001*[a]	2002*[a]		2000	2001/02
Courier		80.0 ab	78.5 ab	6.8	(32.3) abcd	6.7	(30.8) abc		25.8 b
203-PMR-16		67.7 bcde	71.1 abc	6.0	(25.0) abcd	6.2	(26.3) bcd		28.2 a
Grande		92.1 ab	81.9 a	6.8	(32.8) abcd	6.8	(32.3) ab		23.9 bc
Alfetta		56.3 de	45.9 f	4.8	(12.3) efg	5.7	(21.0) def		18.8 g
Mozart		65.7 bcde	57.1 cdef	5.5	(20.0) def	5.7	(21.0) def		22.1 cde
Eclipse		75.1 b	67.5 abcd	4.8	(12.7) efg	4.0	(5.3) ij		22.9 cde
Miami		72.0 bcd	64.5 bcde	4.5	(8.2) fg	5.0	(14.3) fghi		23.4 cde
CDC 0001		69.1 bcde	62.7 bcde	4.0	(5.3) g	4.5	(8.7) hij		23.8 bc
CDC 0109		70.5 bcde	72.4 abc	5.8	(23.3) cde	6.0	(24.8) bcde		25.8 b
Carneval	79.5 (9.7) a	69.3 bcde	67.0 abcd	2.0 (1.7) f	3.5	(2.2) g	3.8	(3.2) j	22.8 (7.2) abc	23.6 bcd
Integra	76.7 (8.3) ab	72.7 bcd	60.1 cdef	2.7 (3.3) ef	4.2	(6.2) g	4.5	(8.7) hij	22.4 (7.0) abc	21.9 cde
Espace	50.7 (4.0) cd	63.2 bcde	60.7 cdef	2.7 (3.3) ef	4.5	(8.7) fg	5.2	(16.3) efgh	36.9 (7.7) ab	23.5 bcde
Nitouche	74.9 (8.0) abc	74.0 bc	62.1 cdef	4.3 (5.8) cd	5.7	(21.5) cdef	4.7	(10.3) ghij	22.3 (6.2) abc	23.7 bc
Radley	64.5 (4.7) bcd	69.9 bcde	56.6 cdef	6.7 (8.2) ab	7.0	(34.3) abc	6.7	(31.3) ab	21.7 (4.7) abc	24.0 bc
AC Melfort	58.3 (2.3) d	58.1 cde	54.0 def	3.3 (4.3) de	4.8	(12.2) efg	5.8	(22.8) bcdef	20.9 (4.2) abc	22.9 cde
Carrera	58.7 (3.0) d	53.9 e	52.3 def	2.3 (2.5) ef	5.0	(14.0) efg	5.7	(21.5) cdef	18.7 (1.2) c	19.5 fg
AC Tamor		69.1 bcde	82.4 a		7.3	(37.5) a	7.3	(37.7) a		23.3 cde
Keoma	62.5 (5.0) bcd	56.7 de	48.7 ef	5.7 (7.0) bc	7.2	(36.0) ab	7.2	(36.0) a	19.6 (2.2) bc	21.3 def
CDC Peko	76 (8.0) bcd	75.1 b	73.1 abc	7.7 (9.5) a	7.2	(36.0) ab	7.2	(36.0) a	22.0 (5.8) abc	23.9 bc
Eiffel	(5.0) abc	68.8 bcde	60.5 cdef		4.8	(12.0) efg	5.5	(19.0) defg		21.2 ef
HSD (Tukey, 0.05)	(4.3)	16.9	16.5	(2.1)		(13.5)		(9.5)		2.4

*a Means and HSD in brackets are rank values

Table 3: Length of internodes between nodes 2 and 3, 5 and 6, and 8 and 9 of field pea varieties in field experiments at Saskatoon (2000) and Outlook (2001/02) to study the relationship between lodging, stem anatomy, stem lignification and resistance to *Mycosphaerella pinodes*

	Length of internodes (cm)									
	2-3					5-6			8-9	
Variety	2000	2001*[a]		2002*[a]		2000		2001/02	2000	2001/02
Courier		1.2	(24.3) a	1.2	(23.0) a			2.2 bc		3.3 abcd
203-PMR-16		1.1	(17.5) a	1.0	(7.7) a			1.5 e		2.6 e
Grande		1.1	(16.0) a	1.3	(35.3) a			2.1 cd		3.3 abcd
Alfetta		1.0	(10.2) a	1.2	(27.5) a			2.1 cd		3.4 abc
Mozart		1.1	(15.7) a	1.3	(32.3) a			2.1 cd		3.3 abcd
Eclipse		1.0	(7.7) a	1.1	(20.3) a			1.9 cd		3.3 abcd
Miami		1.1	(16.3) a	1.0	(12.0) a			2.1 cd		3.3 abcd
CDC 0001		1.2	(29.0) a	1.1	(15.5) a			2.3 bc		3.1 cde
CDC 0109		1.0	(7.3) a	1.1	(22.8) a			1.9 de		3.0 cde
Carneval	1.1 a	1.2	(24.3) a	1.2	(28.8) a	2.2	(2.7) b	2.1 cd	3.2 ab	3.1 cde
Integra	1.2 a	1.2	(32.0) a	1.4	(36.5) a	3.3	(8.0) ab	2.7 ab	4.0 a	3.8 ab
Espace	1.0 a	1.1	(14.2) a	1.3	(27.2) a	2.2	(7.0) ab	2.1 cd	3.1 ab	3.1 cde
Nitouche	1.2 a	1.3	(34.5) a	1.1	(19.2) a	2.6	(4.0) ab	2.3 bc	3.8 a	3.2 bcde
Radley	1.0 a	1.1	(19.3) a	1.1	(22.8) a	2.2	(5.3) ab	2.0 cd	3.1 ab	3.2 bcde
AC Melfort	1.0 a	1.0	(11.8) a	1.0	(9.5) a	1.9	(2.3) b	1.8 de	3.2 ab	2.8 de
Carrera	1.0 a	1.1	(12.8) a	1.1	(15.8) a	2.2	(5.7) ab	2.1 cd	3.5 a	3.1 cde
AC Tamor		1.2	(24.0) a	1.1	(19.2) a			2.0 cd		3.2 abcd
Keoma	0.9 a	1.0	(10.3) a	1.1	(22.2) a	2.2	(4.3) ab	2.0 cd	3.4 ab	3.2 abcd
CDC Peko	1.1 a	1.2	(23.2) a	1.1	(18.5) a	2.1	(5.7) ab	1.9 cde	3.2 ab	3.2 cde
Eiffel	0.4	1.1	(14.2) a	1.6	(39.2) a		(6.8)	2.7 a	1.1	3.8 a
HSD (Tukey, 0.05)			(28.3)		(31.8)			0.4		0.6

*a Mean and HSD are rank values

Table 4: Diameter of internodes between nodes 2 and 3, 5 and 6, and 8 and 9 of field pea varieties in field experiments at Saskatoon (2000) and Outlook (2001/02) to study the relationship between lodging, stem anatomy, stem lignification and resistance to *Mycosphaerella pinodes*

	Diameter of internodes (mm)								
	2-3			5-6			8-9		
Variety	2000		2001/02	2000		2001/02	2000	2001/02*a	
Courier			2.7 abcde			3.2 abcd	4.4	(2.31)	a
203-PMR-16			2.3 de			2.7 cde	3.2	(2.04)	e
Grande			2.7 abcd			3.1 bcde	3.8	(2.19)	abcde
Alfetta			2.2 e			2.8 cde	3.3	(2.08)	cde
Mozart			2.6 abcde			3.1 bcde	4	(2.23)	abc
Eclipse			2.9 abc			3.3 ab	3.9	(2.01)	abcd
Miami			2.4 cde			2.6 e	3.4	(2.08)	cde
CDC 0001			2.7 abcd			3 bcde	3.8	(2.18)	abcde
CDC 0109			2.7 abcd			3.1 bcde	4	(2.22)	abc
Carneval	2.2	(2.7) b	2.4 cde	2.8	(2.7) b	2.6 e	3.7 bc	3.2	(2.05) e
Integra	2.5	(6.7) ab	2.7 abcde	3.4	(8.0) ab	3.1 bcde	4.5 ab	3.9	(2.21) abcd
Espace	2.5	(8.0) ab	2.7 abcde	3.2	(7.0) ab	3 bcde	4.2 abc	3.9	(2.21) abcd
Nitouche	2.2	(3.0) b	2.5 bcde	3.0	(4.0) ab	2.8 bcde	4.2 abc	3.7	(2.15) bcde
Radley	2.3	(4.0) ab	2.7 abcd	3.2	(5.3) ab	3.3 ab	4.4 ab	4.1	(2.25) ab
AC Melfort	2.2	(3.3) b	2.7 abcd	2.8	(2.3) b	2.9 bcde	3.5 c	3.5	(2.12) bcde
Carrera	2.2	(4.0) ab	2.4 bcde	3.1	(5.7) ab	2.7 de	4.0 abc	3.3	(2.08) cde
AC Tamor			2.9 ab			3.2 abc		4	(2.23) abc
Keoma	2.4	(7.3) ab	2.5 bcde	3.0	(4.3) ab	2.7 cde	3.8 bc	3.3	(2.06) de
CDC Peko	2.3	(6.0) ab	3.0 a	3.1	(5.7) ab	3.6 a	4.2 abc	4.4	(2.31) a
Eiffel			2.4 bcde		(6.8)	2.9 bcde	0.8	3.5	(2.12) bcde
HSD (Tukey, 0.05)		(6.3)	0.5			0.5			(0.15)

*a Means and HSD in brackets are square root transformed values

Table 5: Disease severity of *Mycosphaerella pinodes* on field pea varieties in field experiments at Saskatoon (2000) and Outlook (2001/02) to study the relationship between lodging, stem anatomy, stem lignification and resistance to *Mycosphaerella pinodes*

	Whole Plant Rating*b					Pods*c			Stem*d			
Variety	2000*a			2001/2002		2000			2001		2002			2001			2002		
Courier				7.3	(22.2)	cdef				3.3	(27.2)	a	3.7	(31.7)	ab	63	(18.50)	b	75	(28.20)	abcd
203-PMR-16				7.6	(27.8)	abcd				3.0	(22.5)	ab	3.7	(31.7)	ab	63	(13.50)	b	69	(23.00)	bcd
Grande				8.3	(34.8)	abcd				3.0	(22.5)	ab	4.0	(36.2)	ab	63	(18.50)	b	91	(39.00)	a
Alfetta				7.2	(19.5)	def				2.5	(12.2)	bcd	3.0	(22.5)	abc	30	(5.00)	c	63	(18.50)	cd
Mozart				7.2	(19.6)	def				2.0	(5.8)	cd	3.0	(22.5)	abc	46	(9.30)	c	81	(32.70)	abc
Eclipse				6.7	(12.4)	ef				2.2	(8.0)	cd	2.7	(17.2)	bc	63	(18.50)	b	69	(23.00)	bcd
Miami				6.8	(14.8)	def				2.0	(5.8)	cd	3.0	(22.5)	abc	63	(18.50)	b	81	(32.70)	abc
CDC 0001				6.7	(12.3)	ef				2.0	(5.8)	cd	2.8	(19.3)	bc	38	(5.00)	c	55	(14.00)	d
CDC 0109				6.5	(10.3)	f				1.8	(4.3)	d	3.7	(31.7)	ab	38	(5.00)	c	81	(32.70)	abc
Carneval	7.5	(16.0)*e	bc	6.7	(12.2)	ef	1.0	(7.0)	c	1.7	(2.8)	d	2.7	(15.3)	c	38	(5.00)	c	63	(18.50)	cd
Integra	7.0	(4.5)	d	6.5	(10.1)	f	1.0	(7.0)	c	2.0	(5.8)	cd	3.0	(22.5)	abc	38	(5.00)	c	63	(18.50)	cd
Espace	8.0	(16.0)	bc	6.8	(14.6)	ef	3.0	(16.0)	b	2.0	(5.8)	cd	3.0	(22.5)	abc	38	(5.00)	c	75	(28.20)	abcd
Nitouche	8.5	(27.0)	a	7.5	(24.8)	bcde	5.0	(29.0)	a	2.7	(15.3)	bcd	4.0	(36.2)	a	63	(18.50)	b	40	(35.00)	ab
Radley	8.2	(19.7)	ab	6.5	(10.4)	f	4.0	(20.5)	b	2.5	(12.2)	bcd	3.0	(22.5)	abc	38	(5.00)	c	63	(18.50)	cd
AC Melfort	8.5	(27.0)	a	7.0	(17.0)	def	4.0	(20.5)	b	3.0	(22.5)	ab	3.3	(27.0)	abc	63	(18.50)	b	69	(23.30)	abcd
Carrera	8.0	(16.0)	bc	7.5	(24.7)	bcde	4.0	(20.5)	b	1.8	(4.2)	d	3.7	(31.5)	ab	38	(5.00)	b	75	(27.80)	abcd
AC Tamor				8.8	(3.5)	abcd				3.5	(29.8)	a	4.0	(36.2)	a	80	(31.20)	a	81	(32.70)	abc
Keoma	8.0	(16.0)	bc	7.5	(24.6)	bcde	4.0	(20.5)	b	3.3	(27.0)	a	3.7	(31.7)	ab	63	(18.50)	b	88	(37.00)	ab
CDC Peko	7.3	(8.3)	cd	8.6	(37.4)	abcd	1.0	(7.0)	c	3.5	(31.2)	a	4.0	(36.2)	a	63	(18.50)	b	88	(36.70)	ab
Eiffel				7.3	(22.1)	cdef				2.3	(10.0)	cd	3.0	(22.5)	ab	63	(18.50)	b	84	(34.70)	ab
HSD (Tukey, 0.05)	(8.7)			(13.5)			(7.6)			(17.6)			(9.5)			(5.8)			(15.7)		

*a Saskatoon location with only 9 varieties tested in 2000

*b Whole plant assessment based on a 0-9 scale by Xue et al. (1996)

*c Pod assessment based on a 0-5 scale by Tivoli (1977)

*d Stem assessment based on a scale of 0-11 by Horsefall & Barratt (1945), presented in estimated % disease

*e Means and HSD in brackets are rank values

Table 6: Days to flowering, to maturity, yield and number of side branches of field pea varieties in field experiments at Saskatoon (2000) and Outlook (2001/02)to study the relationship between lodging, stem anatomy, stem lignification and resistance to *Mycosphaerella pinodes*

	Days to flowering		Days to maturity		Yield (kg/ha)		Number of branches	
Variety	2001	2002	2001	2002	2001	2002	2001	2001
Courier	59.3 abc	66.3 a	104.7 a	106.7 b	4631.0 abcdefg	4836.0 ab	1.6 c	2.0 bcd
203-PMR-16	60.0 abc	64.3 ab	104.0 b	105.7 bc	3890.0 defg	4249.0 abc	3.0 a	3.5 a
Grande	57.7 cde	62.3 bc	105.0 ab	106.7 b	3874.0 efg	4979.0 a	2.1 abc	1.8 bcd
Alfetta	50.0 g	51.7 k	92.3 j	95.3 j	4806.0 abcdefg	2844.0 c	2.3 abc	1.2 d
Mozart	55.3 f	57.0 gh	99.7 efg	101.0 f	5458.0 a	4526.0 abc	2.6 abc	1.8 bcd
Eclipse	55.3 f	59.7 def	101.0 de	101.0 f	5321.0 ab	5211.0 a	2.2 abc	2.1 bcd
Miami	55.7 ef	55.7 hi	98.0 ghi	97.7 hi	5313.0 ab	4069.0 abc	1.9 abc	2.9 ab
CDC 0001	55.3 f	58.0 fgh	102.0 cd	100.0 fg	3547.0 g	3650.0 abc	2.7 ab	3.0 ab
CDC 0109	58.7 bc	65.3 a	102.0 cd	104.0 cd	5071.0 abcd	4498.0 abc	2.5 abc	2.4 abcd
Carneval	55.3 f	61.0 cde	99.7 efg	99.7 fgh	4283.0 abcdef	4225.0 abc	2.6 abc	2.8 abc
Integra	51.0 g	52.3 jk	93.0 j	98.0 ghi	4845.0 absdef	2595.0 c	1.5 c	1.7 bcd
Espace	54.0 f	55.7 hi	100.0 efg	101.7 ef	5129.0 abc	3551.0 abc	2.3 abc	2.9 ab
Nitouche	55.7 ef	58.0 fgh	101.0 de	101.7 ef	4749.0 abcdefg	3681.0 abc	1.9 bc	1.9 bcd
Radley	56.0 def	57.7 fgh	100.7 def	100.7 f	4209.0 bcdefg	2938.0 bc	2.1 abc	1.3 d
AC Melfort	58.3 bc	59.0 efg	103.3 cd	103.3 de	4758.0 abcdefg	3885.0 abc	3.0 a	2.5 abcd
Carrera	54.0 f	54.3 ij	97.7 hi	97.7 hi	5121.0 abcd	3467.0 abc	1.9 abc	1.5 cd
AC Tamor	58.0 cd	61.7 cd	106.0 a	109.7 a	3769.0 fg	3739.0 abc	2.5 abc	3.0 ab
Keoma	55.0 f	57.0 gh	97.0 i	95.3 j	4899.0 abcdef	2668.0 c	2.3 abc	2.3 abcd
CDC Peko	61.0 a	66.7 a	105.0 ab	106.7 b	3998.0 cdefg	3690.0 abc	2.3 abc	2.5 abcd
Eiffel	51.0 g	53.0 jk	97.0 i	97.3 ji	5359.0 ab	3325.0 abc	1.9 bc	1.9 bcd
HSD (Tukey, 0.05)	2.1	2.5	1.8	2.0	1239.0	1984.0	1.1	1.3

Table 7: Number and proportion of sclerenchyma caps in stem sections of field pea varieties in field experiments at Saskatoon (2000) and Outlook (2001/02) to study the relationship between lodging, stem anatomy, stem lignification and resistance to *Mycosphaerella pinodes*

	No. of sclerenchyma caps						Area of sclerenchyma caps/stem diameter				
	Internode 2-3			Internode 8-9			Internode 2-3		Internode 8-9		
Variety	2000	2001	2002	2000	2001	2002	2000	2001/02	2000	2001	2002
Courier		9.3 a	10.0 a		13.3 a	15.3 a		0.0307 b		0.0269 a	0.0333 ab
203-PMR-16		10.7 a	10.7 a		17.7 a	17.3 a		0.0312 b		0.0224 a	0.0281 b
Grande		11.0 a	11.3 a		14.3 a	18.0 a		0.0393 ab		0.0400 a	0.0397 ab
Alfetta		10.3 a	10.3 a		17.7 a	16.0 a		0.0329 b		0.0233 a	0.0329 ab
Mozart		10.3 a	11.0 a		16.7 a	16.0 a		0.0393 ab		0.0243 a	0.0301 ab
Eclipse		10.7 a	12.7 a		17.7 a	18.3 a		0.0358 b		0.0238 a	0.0385 ab
Miami		10.7 a	9.7 a		15.7 a	17.0 a		0.0274 b		0.0274 a	0.0353 ab
CDC 0001		10.0 a	10.0 a		18.3 a	16.0 a		0.0406 ab		0.0297 a	0.0388 ab
CDC 0109		9.7 a	10.7 a		14.7 a	15.7 a		0.0325 b		0.0297 a	0.0313 ab
Carneval	10.0 a	8.3 a	10.7 a	15.7 a	15.3 a	15.7 a	0.0448 Ab	0.0341 b	0.0385 a	0.0368 a	0.0394 ab
Integra	11.3 a	11.0 a	12.0 a	19.7 a	19.3 a	20.0 a	0.0377 Abcd	0.0414 ab	0.0410 a	0.0393 a	0.0434 a
Espace	9.3 a	10.0 a	10.0 a	17.0 a	15.3 a	16.7 a	0.0355 Bcd	0.0350 b	0.0322 a	0.0277 a	0.0391 ab
Nitouche	9.7 a	12.0 a	10.7 a	17.7 a	17.3 a	19.7 a	0.0441 Abc	0.0423 ab	0.0321 a	0.0353 a	0.0437 a
Radley	10.0 a	10.0 a	10.3 a	15.7 a	14.0 a	15.3 a	0.0317 D	0.0371 b	0.0320 a	0.0334 a	0.0411 ab
AC Melfort	10.0 a	10.3 a	10.7 a	15.7 a	16.7 a	17.3 a	0.0344 Bcd	0.0340 b	0.0345 a	0.0321 a	0.0401 ab
Carrera	10.0 a	10.3 a	10.3 a	16.0 a	17.0 a	17.0 a	0.0325 Cd	0.0323 b	0.0319 a	0.0249 a	0.0334 ab
AC Tamor		10.7 a	12.0 a		16.0 a	17.3 a		0.0322 b		0.0250 a	0.0341 ab
Keoma	11.0 a	10.3 a	10.7 a	15.0 a	15.0 a	14.0 a	0.0487 A	0.0361 b	0.0410 a	0.0305 a	0.0432 ab
CDC Peko	9.7 a	10.7 a	11.0 a	15.0 a	17.3 a	16.0 a	0.0374 Abcd	0.0324 b	0.0412 a	0.0374 a	0.0338 ab
Eiffel		10.0 a	11.0 a		18.7 a	18.3 a		0.0533 a		0.0430 a	0.0446 a
HSD (Tukey, 0.05)							0.0121	0.0149	0.0106	0.0256	0.0151

Table 8: Proportion of supportive tissue in stem sections of field pea varieties in field experiments at Saskatoon (2000) and Outlook (2001/02) to study the relationship between lodging, stem anatomy, stem lignification and resistance to *Mycosphaerella pinodes*

	Area of supportive tissue / stem diameter							
	Internode 2-3					Internode 8-9		
Variety	2000	2001*a		2002*a		2000	2001	2002
Courier		0.0227	(0.1459) bc	0.0305	(0.1740) a		0.1231 abc	0.0980 abc
203-PMR-16		0.0447	(0.2121) abc	0.0409	(0.2025) a		0.1178 abc	0.0992 abc
Grande		0.0163	(0.1227) c	0.0400	(0.1972) a		0.1121 abc	0.0829 abc
Alfetta		0.0808	(0.2839) abc	0.0425	(0.2068) a		0.1543 abc	0.1108 abc
Mozart		0.1057	(0.3231) ab	0.0591	(0.2445) a		0.1741 abc	0.0907 abc
Eclipse		0.0598	(0.2457) abc	0.0674	(0.2540) a		0.1431 abc	0.0965 abc
Miami		0.0341	(0.1805) abc	0.0677	(0.2583) a		0.1525 abc	0.0857 abc
CDC 0001		0.0776	(0.2797) abc	0.0642	(0.2556) a		0.1627 abc	0.1227 abc
CDC 0109		0.0616	(0.2502) abc	0.0661	(0.2518) a		0.0990 bc	0.0620 c
Carneval	0.0408 a	0.0568	(0.2405) abc	0.0537	(0.2333) a	0.1851 a	0.1774 abc	0.1439 a
Integra	0.0932 a	0.0842	(0.2933) abc	0.0783	(0.2793) a	0.1455 ab	0.1531 abc	0.1020 abc
Espace	0.0616 a	0.1132	(0.3423) a	0.0476	(0.2195) a	0.1014 ab	0.1518 abc	0.0752 abc
Nitouche	0.0616 a	0.0771	(0.2617) abc	0.0468	(0.2181) a	0.1687 ab	0.1358 abc	0.1267 abc
Radley	0.0540 a	0.0434	(0.2059) abc	0.0525	(0.2255) a	0.0835 b	0.0903 c	0.0654 bc
AC Melfort	0.0377 a	0.0756	(0.2749) abc	0.0365	(0.1903) a	0.1014 ab	0.1910 ab	0.0861 abc
Carrera	0.0878 a	0.0687	(0.2547) abc	0.0731	(0.2689) a	0.1177 ab	0.1536 abc	0.1115 abc
AC Tamor		0.0165	(0.1275) c	0.0632	(0.2496) a		0.1160 abc	0.0757 abc
Keoma	0.0637 a	0.0277	(0.1614) bc	0.0371	(0.1919) a	0.1201 ab	0.1524 abc	0.1299 abc
CDC Peko	0.0198 a	0.0227	(0.1454) bc	0.0396	(0.1905) a	0.0886 ab	0.0821 c	0.0620 c
Eiffel		0.0941	(0.3113) ab	0.0743	(0.2754) a		0.1962 a	0.1379 ab
$HSD_{(Tukey, 0.05)}$	0.7490		(0.1791)		(0.1523)	0.0991	0.0957	0.0731

*a Means and HSD of arsin transformed data

Table 9: Proportion of pith cavity in stem sections of field pea varieties in field experiments at Saskatoon (2000) and Outlook (2001/02) to study the relationship between lodging, stem anatomy, stem lignification and resistance to *Mycosphaerella pinodes*

	Area of pith cavity / stem diameter					
	Internode 2-3			Internode 8-9		
Variety	2000	2001	2002	2000	2001/2*[a]	
Courier		0.0000	0.0556		0.2180	(0.7699) abc
203-PMR-16		0.0356	0.0359		0.2593	(0.7957) ab
Grande		0.0099	0.0246		0.2504	(0.7897) ab
Alfetta		0.0000	0.0619		0.2548	(0.7930) ab
Mozart		0.0048	0.0457		0.2731	(0.8048) a
Eclipse		0.0145	0.0473		0.2341	(0.7801) abc
Miami		0.0057	0.0519		0.2449	(0.7872) ab
CDC 0001		0.0000	0.0000		0.2378	(0.7826) ab
CDC 0109		0.0021	0.0539		0.2651	(0.7989) a
Carneval	0.0000	0.0023	0.0163	0.1851 a	0.1715	(0.7385) bc
Integra	0.0000	0.0053	0.0757	0.1455 a	0.2563	(0.7944) ab
Espace	0.0426	0.0086	0.0196	0.1014 a	0.2791	(0.8087) a
Nitouche	0.0117	0.0248	0.0222	0.1687 a	0.2420	(0.7850) ab
Radley	0.0000	0.0129	0.0153	0.0835 a	0.2304	(0.7779) abc
AC Melfort	0.0133	0.0433	0.0436	0.1014 a	0.2409	(0.7839) ab
Carrera	0.0323	0.0133	0.0276	0.1177 a	0.2573	(0.7944) ab
AC Tamor		0.0000	0.0531		0.2653	(0.7998) a
Keoma	0.0000	0.0000	0.0087	0.1201 a	0.1504	(0.7246) c
CDC Peko	0.0022	0.0255	0.0055	0.0886 a	0.2659	(0.8000) a
Eiffel		0.0000	0.0263		0.2127	(0.7663) abc
HSD (Tukey, 0.05)				0.2118		(0.0577)

*a Means and HSD of square root transformed data

Table 10: Proportion of pith tissue in stem sections of field pea varieties in field experiments at Saskatoon (2000) and Outlook (2001/02) to study the relationship between lodging, stem anatomy, stem lignification and resistance to *Mycosphaerella pinodes*

	Area of pith tissue / stem diameter							
	Internode 2-3					Internode 8-9		
Variety	2000	2001*[a]		2002*[a]		2000	2001	2002
Courier		0.0819	(0.2841) a	0.1240	(0.3510) ab		0.1810 ab	0.2095 a
203-PMR-16		0.1414	(0.3814) a	0.1153	(0.3448) ab		0.1992 a	0.1682 a
Grande		0.0627	(0.2429) a	0.1008	(0.3204) ab		0.1613 abc	0.1432 a
Alfetta		0.0371	(0.1839) a	0.1159	(0.3452) ab		0.1363 abcd	0.1952 a
Mozart		0.0861	(0.2900) a	0.1234	(0.3568) ab		0.1311 abcd	0.1956 a
Eclipse		0.0952	(0.3091) a	0.1358	(0.3761) a		0.1312 abcd	0.1941 a
Miami		0.0366	(0.1877) a	0.1193	(0.3505) ab		0.1018 cd	0.1849 a
CDC 0001		0.0547	(0.2201) a	0.0861	(0.2956) ab		0.1065 bcd	0.1338 a
CDC 0109		0.0869	(0.2944) a	0.1149	(0.3429) ab		0.1738 abc	0.1825 a
Carneval	0.0502 a	0.0229	(0.1505) a	0.0351	(0.1873) b	0.1386 a	0.1224 abcd	0.1345 a
Integra	0.0281 a	0.0797	(0.2799) a	0.1118	(0.3394) ab	0.0945 a	0.1274 abcd	0.1434 a
Espace	0.1015 a	0.0330	(0.1807) a	0.1069	(0.3309) ab	0.2355 a	0.0987 cd	0.1693 a
Nitouche	0.1417 a	0.0894	(0.3016) a	0.1455	(0.3894) a	0.1765 a	0.1716 abc	0.1411 a
Radley	0.1366 a	0.0643	(0.2529) a	0.1112	(0.3379) ab	0.2935 a	0.1814 ab	0.2075 a
AC Melfort	0.1845 a	0.1185	(0.3437) a	0.1182	(0.3483) ab	0.2789 a	0.0777 d	0.1661 a
Carrera	0.1843 a	0.0467	(0.2021) a	0.1056	(0.3201) ab	0.2135 a	0.1220 abcd	0.1642 a
AC Tamor		0.1275	(0.3449) a	0.1377	(0.3796) a		0.1525 abcd	0.1965 a
Keoma	0.1634 a	0.0769	(0.2781) a	0.1018	(0.3241) ab	0.1417 a	0.1493 abcd	0.1474 a
CDC Peko	0.1081 a	0.1655	(0.4097) a	0.1009	(0.3226) ab	0.2896 a	0.1713 abc	0.1622 a
Eiffel		0.0242	(0.1519) a	0.1435	(0.3877) a		0.1183 bcd	0.1586 a
HSD (Tukey, 0.05)	0.2184		(0.2622)		(0.1755)	0.2184	0.0787	0.089

*a Means and HSD of arsin transformed data

Table 11: Proportion of xylem in stem sections of field pea varieties in field experiments at Saskatoon (2000) and Outlook (2001/02) to study the relationship between lodging, stem anatomy, stem lignification and resistance to *Mycosphaerella pinodes*

	Xylem / stem diameter				
	Internode 2-3			Internode 8-9	
Variety	2000	2001	2002	2000	2001/02
Courier		0.2438 a	0.2261 a		0.1632 ab
203-PMR-16		0.2248 a	0.2438 a		0.1417 ab
Grande		0.2197 a	0.2576 a		0.1682 ab
Alfetta		0.2066 a	0.2446 a		0.1353 b
Mozart		0.2184 a	0.2278 a		0.1342 b
Eclipse		0.2698 a	0.2337 a		0.1544 ab
Miami		0.2684 a	0.2529 a		0.1631 ab
CDC 0001		0.2796 a	0.2424 a		0.1859 ab
CDC 0109		0.2070 a	0.2213 a		0.1361 ab
Carneval	0.3307 a	0.2694 a	0.2796 a	0.5974 a	0.1883 a
Integra	0.2491 a	0.2640 a	0.2580 a	0.4702 a	0.1702 ab
Espace	0.2441 a	0.2310 a	0.2377 a	0.4274 a	0.1526 ab
Nitouche	0.2352 a	0.2340 a	0.2678 a	0.2844 a	0.1437 ab
Radley	0.2721 a	0.2699 a	0.2512 a	0.2942 a	0.1629 ab
AC Melfort	0.2859 a	0.2521 a	0.2406 a	0.2803 a	0.1497 ab
Carrera	0.2560 a	0.1897 a	0.2354 a	0.3272 a	0.1554 ab
AC Tamor		0.2166 a	0.2131 a		0.1351 b
Keoma	0.2461 a	0.1939 a	0.2325 a	0.2720 a	0.1541 ab
CDC Peko	0.2558 a	0.2246 a	0.2310 a	0.3259 a	0.1392 ab
Eiffel		0.2272 a	0.2223 a		0.1468 ab
$HSD_{(Tukey, 0.05)}$	0.1119	0.1075	0.0881	0.4654	0.053

Table 12: Percentage of acid detergent fiber, acid detergent lignin and cellulose in stems of field pea varieties in field experiments at Saskatoon (2000) and Outlook (2001/02) to study the relationship between lodging, stem anatomy, stem lignification and resistance to *Mycosphaerella pinodes*

Variety	ADF	ADL	Cellulose
Carneval	64.11	18.75	45.36
Integra	66.15	17.41	48.74
Espace	64.84	17.96	46.90
Nitouche	63.08	17.08	46.07
Radley	61.22	15.17	46.25
AC Melfort	62.49	17.03	45.45
Carrera	64.01	16.31	47.70
AC Tamor	50.37	12.69	37.67
Keoma	63.00	17.98	45.36
CDC Peko	57.45	13.75	43.57

References:

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Tar'an, B., Warkentin, T.D., Somers, D., Miranda, D., Vandenberg, A., Blade, S., Woods, S., Bing, D., Xue, A.G., DeKoeyer, D., and Penner, G. (2003) Quantitative trait loci for lodging resistance, plant height and partial resistance to *Mycosphaerella* blight in field pea (*Pisum sativum* L.). Theoretical and Applied Genetics (In press).

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Conclusions:

Results from experiments conducted over three years confirmed that there is a strong link between lodging and disease development of *Mycosphaerella pinodes* in pea. While plant height has an influence on lodging and disease, other stem characteristics such as internode diameter and length could not consistently be correlated with these two factors. Microscopic investigation, in contrast, revealed interesting correlations between the

Based on these results it appears that gross-morphological characters such as plant height or stem diameter have little value in predicting resistance to mycosphaerella blight or lodging. The amount of supportive tissue as well as pith tissue may present a marker for the selection of material with higher resistance to the disease and lodging. Most promising may be lignin and fiber analysis as these are relatively faster and cheaper for large-scale application in breeding programs.

Papers/Presentations:

Hashemi, P., Banniza, S., Davis, A., Warkentin, T. and A. Vandenberg (2003): Relationship between lodging, stem anatomy, and reaction to mycosphaerella blight in field pea. [Poster Abstract] Pulse Days 2003, Saskatoon, January 6-7, 2003, p. 64

Hashemi, P., Banniza, S., Davis, A., Warkentin, T.D., and Vandenberg, A. (2002). Relationship between lodging, stem anatomy, stem lignification and reaction to mycosphaerella blight in field pea. Canadian Pulse Crop Research Workshop, Edmonton, December 8-10, 2002.

Hashemi, P., Banniza, S., Davis, A., Warkentin, T.D. & Vandenberg, A. (2001): Relationship between lodging, stem anatomy, and reaction to mycosphaerella blight in field pea. *Biennial Meeting of the North American Pulse Improvement Association*, Fargo, ND, USA, November 5-7 [Abstract].

A paper for submission to a peer reviewed scientific journal is presently in preparation.

Future Research:

We intend to analyze more varieties for fiber and lignin content to confirm the value of these characters as markers. Recombinant inbred lines from populations developed for QTL markers for lodging (Tar'an et al., 2003) are being grown in the field in 2003, and will be analyzed as above to investigate whether QTL markers correlate with fine-anatomical characters and fiber/lignin content. We will be able to determine which

(d) **Personnel:**

Sabine Banniza was appointed Pulse Crop Pathologist in the Crop Development Centre in spring 2000. While she was still responsible for the overall supervision and management, Parvaneh Hashemi took over responsibility for the field and laboratory work.

(e) Equipment:

None

(f) Project Developed Materials:

None

(g) Project Photos:

Stem section photos have been produced and will be presented in the manuscript, which is in preparation.

(h) Acknowledgement:

The Saskatchewan Agricultural Development Fund has been acknowledged in all presentations where this research project was mentioned.